eFuses: Use Cases, Benefits, And Design In The System Context

ADAS makes it necessary to adopt new approaches to overcurrent protection.

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In recent years, the automotive industry has been one of the drivers of innovation in the field of electrical and electronic system safety. This is primarily due to the rapid uptake and, in some cases, already mandatory use of advanced driver assistance systems (ADAS) as well as to the first steps toward (partially) autonomous vehicles.

In conventional safety systems, the off state can be assumed to be safe. With ADAS, this is no longer automatically the case. This makes it necessary to adopt new approaches to fuse protection, which will subsequently spread to other industries.

One recent innovation is the electronic fuse, or eFuse. Traditionally, the vehicle electrical system was protected by sacrificial fuses. These reliably disconnect the power supply in the event of overcurrents, but in the process, they switch off individual components or, depending on their position, even whole sections of the vehicle electrical system. The eFuse offers various options for maintaining functionality in the event of a fault.

The simplest option is based on the fact that the eFuse is a transistor that severs the connection if the current is too high. In contrast to sacrificial fuses, which require a certain amount of time to absorb enough thermal power to melt, this disconnection happens much faster and, more importantly, it is also reversible. That makes it possible to tentatively reestablish the connection after it’s been severed. Provided the current doesn’t spike again, the connection can be left up and running.

More complex approaches involve combinations of several eFuses. These can maintain the power supply to individual safety-relevant sections of the vehicle electrical system while switching off other, less relevant sections. This method is particularly useful if the overcurrent isn’t the result of a sudden short circuit, but rather drifts slowly higher than the normal range. In many cases, it is then still possible for the vehicle to reach a workshop before the safety-critical functions have to be switched off and the vehicle must come to a standstill. At the very least, however, the driver can be informed in good time and bring the vehicle to a safe stop at the side of the road.

System simulations are an essential step in designing both the eFuses themselves and the vehicle electrical system they protect. In such simulations, the entire vehicle electrical system is simulated using different load scenarios based on real measured journeys. This makes it possible to test how different types of eFuses react in practice and to determine the optimum type for a specific vehicle electrical system architecture. Moreover, this architecture itself can be optimized at the same time, as the use of eFuses opens up new possibilities here. It’s potentially possible to remove redundant connections or to reduce the cross-sections of many cables. The latest vehicle electrical network topologies such as zone-based or domain-based architecture are also an excellent fit with the eFuse concept. To guarantee the necessary safety levels, the optimized architectures must be simulated with fault injection. An optimization algorithm can be used to determine the optimum, or most cost-effective, variant while maintaining the required level of safety.

Such system simulations are based on comprehensive, validated simulation libraries that can be used to simulate vehicle electrical systems. Load and error scenarios must also be available. Various industry and research associations are working to build up these kinds of libraries. In the next few years, they will likely be available for various system modeling languages such as Modelica, MATLAB Simscape, or System C.